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Patentanmeldung Nr. Patent application No. Demande de brevet n°

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For the President of the European Patent Office

Le Président de l'Office européen des brevets p.o.

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Luminaire

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Luminaire

The invention relates to a luminaire comprising:
a light directing element having a light emission window,
said light directing element has a shape for directing light originating from an electric light source to be accommodated into an optical-fiber system.

The invention further relates to a dynamic road marking unit.

Such a luminaire is known from EP-615094. In the known luminaire the light-directing element is a reflective surface of a concavely-shaped reflector, the light source being arranged on an optical axis of the reflector. The shape of the reflective surface is calculated with an algorithm, and thus optimized with respect to coupling light into a light entrance surface of an optical fiber system. The algorithm further taking into account that the luminous intensity had to be constant as much as possible over the light entrance surface of the optical-fiber system. Thus a high efficacy light output of the system is obtained. However, it appeared that the known luminaire still has as a disadvantage that the algorithm used, does not yield an optimized shape for the reflective surface for the accommodated light sources. As a result the efficiency and uniformity is of the known luminaire is not optimal for the accommodated light sources.

It is an object of the invention to obtain a luminaire of the type as described in the opening paragraph in which the disadvantage is counteracted. Thereto the luminaire according to the invention is characterized in that said shape is calculated according to a ray-tracing algorithm taking into account that said light source to be accommodated is voluminous. Ray-tracing is a method enabling to create images on a computer using software. Input data for the algorithm are objects and light sources characteristics, specified with respect to shape, position, color and texture and position of the light source. The software actually mathematically models light rays, either reflected and/or refracted. Part of the data input for example can be realized by using an interactive modeling system, like a

CAD software package . In the algorithm used to determine the shape of the reflective surface of the known luminaire, said shape is optimized for a light source which is infinitely small, i.e. a light source which is considered as a point and without taking into account characteristics of the optical fiber. However, in practice a light source always has a finite dimension, i.e. is voluminous and the optical fiber characteristics change the way of optimization. The inventive measure, has the advantage that in a relatively simple way it is enabled via iterative steps in the calculation, to design and obtain a shape of the reflective surface via which light from a voluminous light source, can be coupled via an entrance into an optical fiber system with a relatively high efficacy and with a relatively constant luminous intensity. The entrance of the optical fiber system is taken as a two dimensional matrix of elementary surfaces. Efficiency and intensity distribution uniformity are determined by calculation and comparison of the light falling on each respective elementary surface. The voluminous light source is accounted for in the ray tracing method by data input of a real measurement of a voluminous light source, and by subsequently deal with said voluminous light source as a lot of punctual light sources. For the lot of punctual light sources a compromise solution is calculated which is satisfactory primary with respect to efficiency and secondary with respect to intensity distribution uniformity. It is an additional advantage of the inventive luminaire that it is enabled thereby to use a light directing element which is small compared to the light source with maintenance of high efficiency and homogeneity of the light intensity distribution.

A relatively simple and relatively easily calculation of the shape of the reflective surface, which shape is relatively easily manufacturable as well, is obtained in the case that the shape is construed from n solid of revolutions of parabolic sectors, wherein the adjoining parabolic sectors form an integral surface, i.e. a surface which is smooth and is free from disruptions. Calculation time is reduced and is especially simple when each parabolic sector is calculated and optimized one after the other. In particular the following sets of equations for defining each parabolic sector are appropriate:

$$a(i) = (z(i) - z(i + 1)) / (x(i)^2 - x(i+1)^2)$$

$$b(i) = a(i)$$

$$c(i) = (x(i)^2 * z(i + 1)) - ((x(i + 1)^2 * z(i)) / (x(i)^2 - x(i + 1)^2)$$

wherein:

a(i), b(i) and c(i) are polynomial coefficients of the parabolic sectors

[illegible]

x, y, z are coordinates of the i^{th} surface of revolution of the parabola in a linear x, y, z tri-coordinate system;

the coordinates x(i), z(i) , x(i+1), z(i+1) are limits of the i^{th} parabolic sector in a plane xz;

i is an integer running from 1 to n.

Calculations with various coefficients and coordinates, hence various defined parabolic sectors, enable to determine appropriate light directing elements with respect to efficacy and homogeneity of the light distribution.

Said calculation is usable for a luminaire in which the light-directing element is chosen from the group consisting of a reflector, a refractor and a combination thereof. Each type of light-directing element requiring a specific calculation, for example in the case a refractor is involved, the refractive index of the material of which the refractor is made has to be accounted for. As said light-directing elements can be relatively small with respect to the light source, the use of said element in relatively small luminaires is enabled. Hence, a combination of said luminaire with a relatively small light source, i.e. an electric lamp with a small light generating element, is preferable. Light sources having said small light generating element for example are Light Emitting Diode's and high intensity discharge lamps, i.e. lamps with a pair of mutually opposed electrodes that define and electrode path of a certain length, for example a length of 3 mm. Light Emitting Diode's have the additional advantage over high intensity discharge lamps that synthetic materials are applicable for the entrance of the optical fiber system, as with Light Emitting Diode's a relatively low temperature is obtained during operation of the luminaire.

In the inventive luminaire the luminous intensity coupled into an optical fiber system is relatively constant over the surface for a voluminous light source. As a result, the inventive luminaire is in particular suitable for the case in which the optical fiber system comprises a bundle of optical fibers, as in said case each respective fiber is provided with light of practically the same intensity/flux. It is thus enabled to provide light from one light source to emerge from optical fiber ends at several locations with practically the same intensity. In this respect a further improvement of the calculation, and thus the shape of the light-directing element, is obtained when in the ray-tracing algorithm is accounted for the path length of each wave through the respective fiber, according to the following formula:

efficacy of respective ray = 1/10^(length of fiber/cos(angle of incidence at entrance of fiber)*attenuation(λ)/10)

wherein λ = wavelength range.

Said further improvement can be even further improved if in the algorithm the radius of curvature of the optical fibers is accounted for, i.e. according to the formula:

theta curve = arccosinus(Internal radius of curvature /(Internal radius of curvature + monofiber diameter))

Thus, criteria of angle of incidence of each respective ray, fiber attenuation for each respective optical fiber of the bundle of optical fibers and radius of curvature of the optical fibers are accounted for. The calculation comprises steps accounting as well for dependency of the refraction index on the wavelength range to be guided through the optical fibers. When a glass rod is provided at the end of the optical fiber a still further improved homogeneous intensity of the light distribution is attained. Providing light of practically the same intensity to several locations is applicable in luminaires as used in dynamic road marking systems. In this respect it is favorable when the luminaire has a shaped housing adapted to a saw-cut recess for accommodating the unit. Such a luminaire can be provided in a road surface in a relatively simple way. Provision of said glass rod at said end offer the luminaire the additional advantage that the optical fiber is protected by it from damage/pollution, which is of particular importance in dynamic road marking systems.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter in a drawing, wherein:

Fig. 1 a schematic arrangement of a luminaire according to the invention and an optical fiber harness;

Fig. 2 a schematic built-up of a reflector body of a luminaire according to the invention;

Fig. 3 a dynamic road marking unit comprising the luminaire of Fig. 1.

Fig. 1 shows a luminaire 1 comprising a light directing element 3, in the figure a reflector, having a light emission window 5 and having a space 6 enclosed by the light-directing element and its light emission window into which space a light source 7 is arranged. Said reflector has a shape for directing light originating from the electric light source 7 into an optical-fiber system 9 positioned in front of the light emission window. The optical fiber [illegible]

[illegible]

electric light source is a Light Emitting Diode. It is further shown that the reflector is relatively small compared to the light source.

In Fig. 2 a perspective view of a reflector 3 of a luminaire according to the invention, with a light emission window 5, is shown. The reflector has a shape which is made of five solids of revolution of parabolic sectors 13 defining a surface 15. At borders 17 of adjoining parabolic sectors the surface 15 is smooth and is free from disruptions. The parabolic sectors are parts of parabola defined according to the following set of equations:

$$a(i) = (z(i) - z(i + 1)) / (x(i)^2 - x(i+1)^2)$$

$$b(i) = a(i)$$

$$c(i) = (x(i)^2 * z(i + 1)) - ((x(i + 1)^2 * z(i)) / (x(i)^2 - x(i + 1)^2)$$

wherein:

a(i), b(i) and c(i) are polynomial coefficients of the parabolic sectors in such a way that coordinates of each point of the reflective surface fulfill the condition:

$$a(i)*x^2 + b(i)*y^2 - z + c(i) = 0;$$

x, y, z are coordinates of the i^{th} surface of revolution of the parabola in a linear x, y, z tri-coordinate system;

the coordinates x(i), z(i) , x(i+1), z(i+1) are limits of the i^{th} parabolic sector in a plane xz;

in the case of Figure 2, i is an integer running from 1 to 5.

Fig. 3 shows an embodiment of a dynamic road marking unit 19 having a housing 21 with a shape which is a combination of a circular segment cylinder 23 and a circular cylinder 25 perpendicular to an emission surface 27. The circular cylinder part of the unit accommodates the luminaire 1 and the optical fiber system 9 of Fig. 1. The optical fibers 11 of the optical fiber system extend from about the emission window 5 of the luminaire to openings 29 in the emission surface. Each opening is closed by a glass rod 31, the glass rod thus being positioned at an end of a respective optical fiber. The emission surface of the unit protrudes for a height h above road surface R, h being in the range from 2-5 mm.

CLAIMS:

1. A luminaire comprising:

a light directing element having a light emission window,

said light directing element has a shape for directing light originating from an electric light source to be accommodated into an optical-fiber system,

characterized in that said shape is calculated according to a ray-tracing algorithm taking into account that said light source to be accommodated is voluminous.

2. A luminaire according to claim 1, characterized in that the shape is made of n surfaces of revolution of parabolic sectors, wherein adjoining parabolic sectors form an integral surface.

3. A luminaire according to claim 2, characterized in that the parabolic sectors are parts of parabola defined according to the following set of equations:

$$a(i) = (z(i) - z(i + 1)) / (x(i)^2 - x(i+1)^2)$$

$$b(i) = a(i)$$

$$c(i) = (x(i)^2 * z(i + 1)) - ((x(i + 1)^2 * z(i)) / (x(i)^2 - x(i + 1)^2)$$

wherein:

a(i), b(i) and c(i) are polynomial coefficients of the parabolic sectors in such a way that coordinates of each point of the reflective surface fulfill the condition:

$$a(i)*x^2 + b(i)*y^2 - z + c(i) = 0;$$

x, y, z are coordinates of the i^{th} surface of revolution of the parabola in a linear x, y, z tri-coordinate system;

the coordinates x(i), z(i) , x(i+1), z(i+1) are limits of the i^{th} parabolic sector in a plane xz;

i is an integer running from 1 to n.

4. A luminaire according to claim 1, 2 or 3, characterized in that the light-directing element is chosen from the group consisting of a reflector, a refractor and a combination thereof.

5. A luminaire according to claim 1, 2, 3, or 4, characterized in that the light source is an electric lamp.

6. A luminaire according to claim 5, characterized in that the electric lamp is a Light Emitting Diode.

7. A luminaire according to any one of the preceding claims, characterized in that the optical fiber system comprises a bundle of optical fibers.

8. A luminaire according to claim 7, characterized in that a glass rod is positioned at an end of the optical fiber.

9. A dynamic road-marking unit comprising a luminaire according to any one of the preceding claims.

10. A dynamic road-marking unit according to claim 9, characterized in that the luminaire has a shaped housing adapted to a saw-cut recess for accommodating the unit.

ABSTRACT:

A luminaire 1 comprising a light directing element 3, e.g. a reflector, having a light emission window 5. Said reflector has a shape for directing light originating from an electric light source 7 into an optical-fiber system 9 positioned in front of the light emission window. The optical fiber system comprising a bundle of optical fibers 11. Said shape is calculated according to a ray-tracing algorithm taking into account that said light source is voluminous, e.g. a Light Emitting Diode. The reflector has a shape which is made of n solids of revolution of parabolic sectors 13, wherein said (adjoining) parabolic sectors form an integral surface 15.

Fig. 1

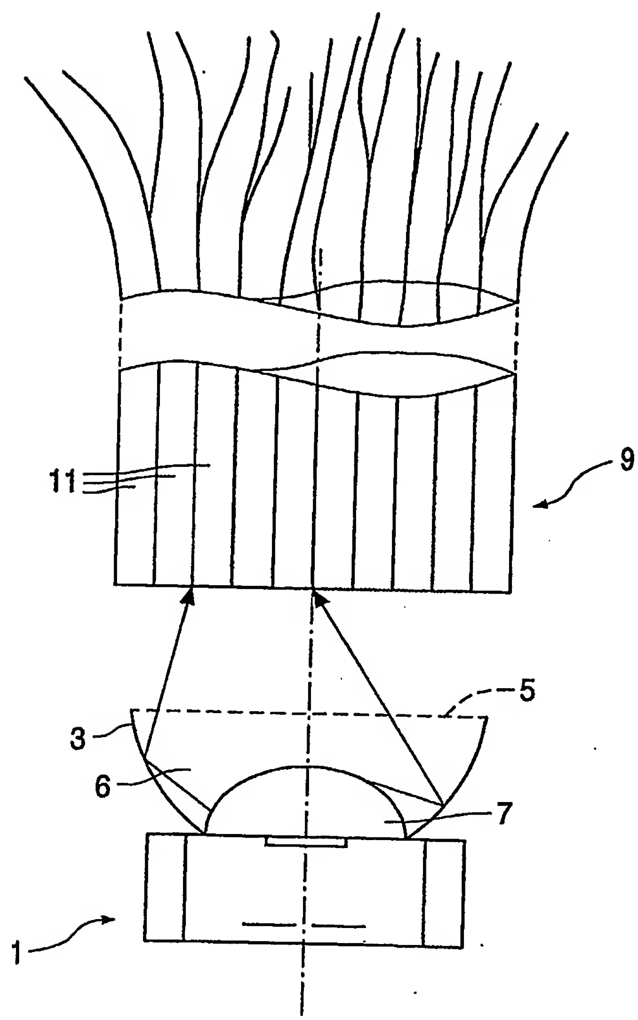

FIG. 1

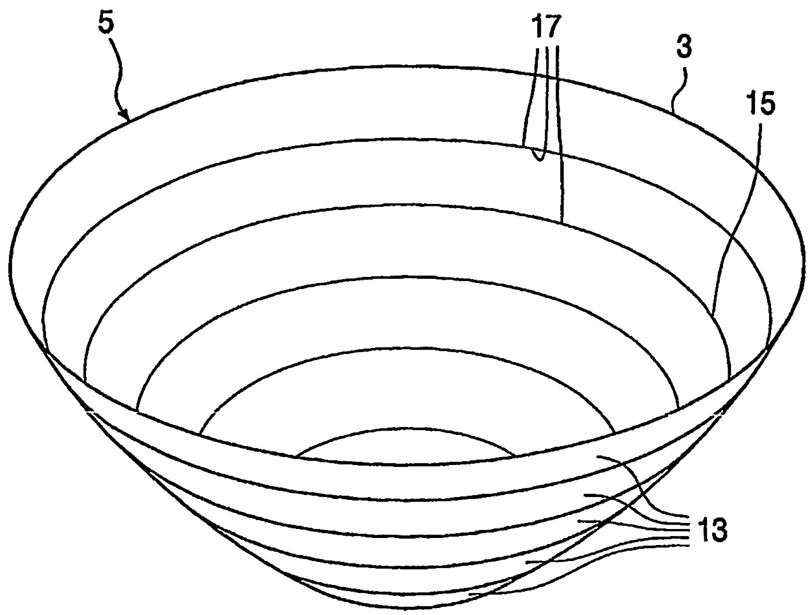

FIG. 2